Vocal Tract Shapes in Different Singing Functions Used in Musical Theater Singing—A Pilot Study

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Summary: Objective. Singing styles in Musical Theater singing might differ in many ways from Western Classical singing. However, vocal tract adjustments are not understood in detail.

Material and Methods. Vocal tract shapes of a single professional Music Theater female subject were analyzed concerning different aspects of singing styles using dynamic real-time magnetic resonance imaging technology with a frame rate of 8 fps. The different tasks include register differences, belting, and vibrato strategies.

Results. Articulatory differences were found between head register, modal register, and belting. Also, some vibrato strategies ("jazzy" vibrato) do involve vocal tract adjustments, whereas others (classical vibrato) do not.

Conclusions. Vocal tract shaping might contribute to the establishment of different singing functions in Musical Theater singing.

Key Words: Musical Theater–Belting–Vocal tract–Magnetic resonance imaging–Vibrato–Chest voice–Head voice–Modal register.

INTRODUCTION

Musical Theater singing differs in numerous ways from Western Classical singing. One reason could be that, in contrast to most classical voice performances, the use of microphones and electronic amplification are now commonly used by Musical Theater singers. This allows for the use of "uneconomic" voice qualities such as breathy or rough voice (as heard in Rock and Pop styles) to be used as valid aesthetic choices.

As Musical Theater in America developed in the early 20th Century, the lack of amplification and the aesthetic of music made for and enjoyed by the common man required a loud singing technique, which differed in character from traditional classical vocal ideals. Such technique was often denoted as belting. Since then, the term belting has been often used and defined in many different ways. Today, there is no agreement in voice pedagogy nor in the scientific world how belting should be defined. In addition, there are descriptions of subtypes of belting such as ringy, brassy, nasal, speech-like, and heavy.[1]

Some authors have postulated that belting might be related to a register function.[2,3] In this respect, it is assumed that belting is considered an extension of the modal or chest register to higher fundamental frequencies (F_0s). However, belting could also be related to aesthetic or timbral aspects of singing production.

Compared with Western Classical singing technique, it has been shown that belting exhibits differences in all aspects of voice production. It is often assumed that belting is associated with a loud voice[4–7] and high subglottic pressure.[7,8] In a recent study by Sundberg et al,[9] however, it was shown that the degree of subglottic pressure varied according to the substyle of belting. The authors observed high subglottic pressure only for *heavy belt*, whereas the values for *ringy* and *brassy* belting substyles were within the range found in the female classical singing style.[9]

Many studies have focused on the voice source. Using flow glottograms, it was found that the voice source fundamental was stronger for the female classical voice (head register) compared with *heavy belt*.[9] Also, the closed quotient was greater for the belting substyles.[9] This last finding agrees with numerous electroglottographic studies in which the contact quotient was greater for belting.[3,4,10,11] Lebowitz and Baken[12] were not able to confirm such differences between "*belt*" and "*legit*" in their study. Legit is a term often used to denote a classically based technique, primarily using head register in females, used in Musical Theater. An increased speed quotient for belting was also found.[12] As a consequence, it might be safe to assume that vocal fold oscillatory patterns differ between *belting* and *legit* singing styles. It can also be assumed that different registers are being used and that different muscle actions are being used. Indeed, in electromyographic studies by Estill,[4] it was found that vocalis muscle activity was greater for belting in comparison with Western Classical singing. Furthermore, muscles crucial for vocal tract shaping showed different activation for belting in contrast to female operatic (classical) singing.[4] Later, Kochis-Jennings et al[13] found different laryngeal muscle activities for what the authors denoted as chest, chestmix, headmix, and head.

It has been often assumed that there are special vocal tract configurations associated with belting. Osborne[6] has pointed out that belting is associated with an open vowel configuration. In contrast to operatic singing, some authors observed a higher first formant frequency for belting.[3,7,9] Schutte and Miller[3] suggested that this would be caused by a higher larynx position for belting. They postulated that this might be necessary to match first formant to the second harmonic for open vowels. A comparable tuning strategy was also reported, recently, by Bourne and Garnier[14] for the "*chesty belt*," whereas *legit* failed to show

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such a tuning strategy. However, Sundberg et al[9] were not able to confirm these results using inverse filtering techniques. Other tuning strategies were found for /i/ and /e/ by Bestebreurtje and Schutte.[15]

Furthermore, tongue position may be an integral element in belting.[5,16] Here, it was observed that the tongue was elevated. Titze and Worley[17] suggested from their modeling experiments that classical singing is associated with an inverse trumpet shape of the vocal tract, whereas belting is related to a trumpet shape configuration. Because modifications of vocal tract shape are mostly not visible from the outside, differences between Musical Theater singing and Classical singing are not yet understood in detail.

Most studies on Musical Theater singing have focused on belting with several authors investigating an alternate speech-like type of phonation. However, in contrast to belting for which sometimes a lack of vibrato is postulated,[5,6] there are also different vibrato techniques used in Musical Theater singing when compared with Western Classical singing. Very little investigation of vocal tract shape differences in varying Musical Theater vibrato types has been undertaken so far.

Dynamic real-time magnetic resonance imaging (MRI) techniques for some time have offered the opportunity to analyze two-dimensional vocal tract shapes in singing. Such techniques have been successfully applied in studies concerning different singing functions such as high female singing,[18,19] registers,[20–22] and yodeling.[23] The present study was performed to analyze vocal tract shape comparing different vocal functions used in Musical Theater singing in a single professional Musical Theater female subject.

It has been hypothesized that vocal tract shape changes when varying singing tasks. Therefore, it was expected that (1) the vocal tract configuration would differ between heavy belt on one hand and head voice on the other, (2) the vocal tract shape differs between modal and head register with respect to different vowel conditions, and (3) there would be vocal tract shape differences when using different vibrato strategies.

MATERIAL AND METHODS

All experiments were performed in a single professional female Musical Theater singer and pedagogue subject. The subject was the same subject analyzed by Sundberg et al,[9] in a previous study. At the time of the recordings, the subject did not complain of any vocal symptoms. Laryngeal pathologies were excluded by videostroboscopic examinations.

Experiments were performed radiologically with the 3.0 T TIM TRIO (Siemens, Erlangen, Germany) MRI device in a supine position.[22] Real-time MRI was performed with a temporal resolution of 8 images per second. The detailed MRI setup was identical to previous studies.[22] The audio signal was recorded by means of an optic microphone (Fa. MR confon, Magdeburg, Germany, OptiMRI Noise Reduction Software, Fa. Optoacoustics Ltd., Or-Yehuda, Israel). As in our previous studies, the subject was provided with the audio signal over headphones (Fa. MR confon, Magdeburg, Germany) as acoustic feedback.

In the first experiment, the subject was asked to sing ascending pitches from G3 up to C6 on the vowel /e/ in either head voice or belting, respectively. Because the definition of belting might be considered as heterogeneous in the literature, the authors accepted the subject's own definition of the heavy belt substyle, described before.[9] Because other researchers might differ with this definition, the authors provide representative online Supplementary video material of all experiments including the original audio signal. The vowel /e/ was chosen because some researchers and many Musical Theater singers report that belting is best accomplished using this or the vowel /a/. However, because register and vowel choice might contribute to different Musical Theater singing styles, the same subject was asked in a second experiment to sing on the vowels /a, e, i, o, u/ in a descending triad (C5, G4, E4, C4) either in modal or in head register, respectively.

Because it has been widely accepted that varying widths of the pharyngeal cavity impact vocal timbre, the subject was asked to sustain the vowel /a/ on C4 with a (1) neutral pharynx position, (2) constricted pharynx position, and (3) wide pharynx position.

Finally, because vibrato type might differ between styles, subject was asked to produce two different kinds of vibrato on G4 on the vowel /ae/. The subject herself denoted the vibrato styles as (1) "classical" and (2) "jazzy" vibrato.

During the MRI recordings, four experts were present as follows: (1) a singing pedagogue and full professor of Musical Theater singing, (2) a professional Musical Theater singer and medical student, (3) and (4) both otolaryngologists and Western Classical singers. The experts checked that the subject produced the desired tasks. Directly after each sequence, the subject was asked if she felt that she had produced the tasks acceptably. Only sequences found acceptable by all experts as well as by the singer herself were subsequently analyzed.

In each frame of the MRI material, a series of measures were taken, as described previously.[22] In addition, the supralaryngeal diameter was defined as the shortest distance between the epiglottis and the arytenoid cartilages.

In the audio recording, the F_0 was identified using *PRAAT* software (University of Amsterdam, the Netherlands). The relationship between F_0, task, and each of the MRI measures was then analyzed. Due to the fact that this study is a single subject study, comparing statistical analysis for mean values for the distances and angles with respect to the registers was not feasible.

RESULTS

In the first experiment, on the vowel /e/, the subject showed clear vocal tract shape differences between the head voice and belting tasks for the different pitches (Figure 1 and online Supplementary Video 1). Results showed greater lip opening, jaw opening, and a smaller pharynx width for the belting task. Furthermore, the larynx position was found to be much higher in belting. Finally, the epilaryngeal tube, as measured by means of the supralaryngeal diameter, was found much narrower for the belting task. The changes with rising pitch were